

SECTION 34 41 20 -
LED PILOT PROGRAM
CFW LED Residential
100 – 150W Replacement
Specification

December 2013

City of Fort Worth
Specification for Residential LED Roadway Luminaires

PART 1 – GENERAL

1.1. REFERENCES

The publications listed below form a part of this specification to the extent referenced. Publications are referenced within the text by their basic designation only. Versions listed shall be superseded by updated versions as they become available.

- A. American National Standards Institute (ANSI)
 - 1. C136.2-2004 (or latest), American National Standard for Roadway and Area Lighting Equipment—Luminaire Voltage Classification
 - 2. C136.10-2010 (or latest), American National Standard for Roadway and Area Lighting Equipment - Locking-Type Photocontrol Devices and Mating Receptacle Physical and Electrical Interchangeability and Testing
 - 3. C136.15-2011 (or latest), American National Standard for Roadway and Area Lighting Equipment – Luminaire Field Identification
 - 4. C136.22-2004 (R2009 or latest), American National Standard for Roadway and Area Lighting Equipment – Internal Labeling of Luminaires
 - 5. C136.25-2009 (or latest), American National Standard for Roadway and Area Lighting Equipment – Ingress Protection (Resistance to Dust, Solid Objects and Moisture) for Luminaire Enclosures
 - 6. C136.31-2010 (or latest), American National Standard for Roadway Lighting Equipment – Luminaire Vibration
 - 7. C136.37-2011 (or latest), American National Standard for Roadway and Area Lighting Equipment - Solid State Light Sources Used in Roadway and Area Lighting
- B. American Society for Testing and Materials International (ASTM)
 - 1. B117-09 (or latest), Standard Practice for Operating Salt Spray (Fog) Apparatus
 - 2. D1654-08 (or latest), Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
 - 3. D523-08 (or latest), Standard Test Method for Specular Gloss
 - 4. G154-06 (or latest), Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials
- C. Council of the European Union (EC)
 - 1. RoHS Directive 2002/95/EC, on the restriction of the use of certain hazardous substances in electrical and electronic equipment
- D. Federal Trade Commission (FTC)
 - 1. Green Guides, 16 CFR Part 260, Guides for the Use of Environmental Marketing Claims
- E. Illuminating Engineering Society of North America (IESNA or IES)
 - 1. DG-4-03 (or latest), Design Guide for Roadway Lighting Maintenance
 - 2. HB-10-11 (or latest), IES Lighting Handbook, 10th Edition
 - 3. LM-50-99 (or latest), IESNA Guide for Photometric Measurement of Roadway Lighting Installations
 - 4. LM-61-06 (or latest), IESNA Approved Guide for Identifying Operating Factors Influencing Measured Vs. Predicted Performance for Installed Outdoor High Intensity Discharge (HID) Luminaires
 - 5. LM-79-08 (or latest), IESNA Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products

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6. LM-80-08 (or latest), IESNA Approved Method for Measuring Lumen Maintenance of LED Light Sources
7. RP-8-00 (or latest), ANSI / IESNA American National Standard Practice for Roadway Lighting
8. RP-16-10 (or latest), ANSI/IES Nomenclature and Definitions for Illuminating Engineering
9. TM-3-95 (or latest), A Discussion of Appendix E - "Classification of Luminaire Lighting Distribution," from ANSI/IESNA RP-8-83
10. TM-15-11 (or latest), Luminaire Classification System for Outdoor Luminaires
11. TM-21-11 (or latest), Projecting Long Term Lumen Maintenance of LED Light Sources
- F. Institute of Electrical and Electronics Engineers (IEEE)
 1. IEEE C62.41.2-2002 (or latest), IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and less) AC Power Circuits
 2. ANSI/IEEE C62.45-2002 (or latest), IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits
- G. National Electrical Manufacturers Association (NEMA)
 1. ANSI/NEMA/ANSI C78.377-2008 (or latest), American National Standard for the Chromaticity of Solid State Lighting Products
- H. National Fire Protection Association (NFPA)
 1. 70 – National Electrical Code (NEC)
- I. Underwriters Laboratories (UL)
 1. 1449, Surge Protective Devices
 2. 1598, Luminaires
 3. 8750, Light Emitting Diode (LED) Equipment for Use in Lighting Products

1.2. RELATED DOCUMENTS

- A. Contract Drawings and conditions of Contract (including General Conditions, Addendum to the General Conditions, Special Conditions, Division 01 Specifications Sections and all other Contract Documents) apply to the work of this section.
 - a. See the separate Specification for Adaptive Control and Remote Monitoring of LED Roadway Luminaires for additional driver performance and interface requirements.

1.3. DEFINITIONS

- A. Lighting terminology used herein is defined in IES RP-16. See referenced documents for additional definitions.
 1. Exception: The term “driver” is used herein to broadly cover both drivers and power supplies, where applicable.
 2. Clarification: The term “LED light source(s)” is used herein per IES LM-80 to broadly cover LED package(s), module(s), and array(s).

1.4. QUALITY ASSURANCE

- A. Before approval and purchase, Owner may request luminaire sample(s) identical to product configuration(s) submitted for inspection. Owner may request IES LM-79 testing of luminaire sample(s) to verify performance is within manufacturer-reported tolerances.

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- B. After installation, Owner may perform IES LM-50 field measurements to verify performance requirements outlined in Appendix A, giving consideration to measurement uncertainties outlined in IES LM-61.

1.5. LIGHTING SYSTEM PERFORMANCE

- A. Energy Conservation
 - 1. Connected Load
 - a. Luminaires shall have maximum nominal luminaire input wattage as specified for each luminaire type in Appendix A.
 - 2. Lighting Controls
 - a. See separate controls specification identified in section 1.2 above, if applicable.
 - b. See section 2.1-B below for driver control interface and performance requirements.
 - c. See section 2.1-K below for photocontrol receptacle requirements.
- B. Photometric Requirements
 - 1. Luminaires shall meet the general criteria provided in the body of this specification and the particular criteria for each luminaire type defined in Appendix A.

1.6. REQUIRED SUBMITTALS FOR EACH LUMINAIRE TYPE DEFINED IN APPENDIX A

- A. General submittal content shall include
 - 1. Completed Appendix E submittal form
 - 2. Luminaire cutsheets
 - 3. Cutsheets for LED light sources
 - 4. Cutsheets for LED driver(s)
 - a. If dimmable LED driver is specified, provide diagrams illustrating light output and input power as a function of control signal.
 - 5. Cutsheets for surge protection device, if applicable
 - 6. Instructions for installation and maintenance
 - 7. Summary of luminaire recycled content and recyclability per the FTC Green Guides, expressed by percentage of luminaire weight
- B. LM-79 luminaire photometric report(s) shall be produced by the test laboratory and include
 - 1. Name of test laboratory
 - a. The test laboratory must hold National Voluntary Laboratory Accreditation Program (NVLAP) accreditation for the IES LM-79 test procedure or must be qualified, verified, and recognized through the U.S. Department of Energy's CALiPER program. For more information, see <http://ts.nist.gov/standards/scopes/eelit.htm> or www.ssl.energy.gov/test_labs.html.
 - 2. Report number
 - 3. Date
 - 4. Complete luminaire catalog number
 - a. Provide explanation if catalog number in test report(s) does not match catalog number of luminaire submitted
 - i. Clarify whether discrepancy does not affect performance, e.g., in the case of differing luminaire housing color.

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- ii. If nominal performance of submitted and tested products differ, submit additional LM-79 report(s) and derivation as indicated in Appendix C.
- 5. Description of luminaire, LED light source(s), and LED driver(s)
- 6. Goniophotometry
- C. Calculations and supporting test data per Appendix B indicating a lumen maintenance life of not less than 36,000 operating hours
- D. Computer-generated point-by-point photometric analysis of maintained photopic light levels as per Appendix A
 - 1. Calculations shall be for maintained values, i.e. Light Loss Factor (LLF) < 1.0, where $LLF = LLD \times LDD \times LATF$, and
 - a. Lamp Lumen Depreciation (LLD)
 - i. Shall be 0.95.
 - ii. Shall be the percentage of initial output calculated in section 1.6-C.
 - b. Luminaire Dirt Depreciation (LDD) = 0.90, as per IES DG-4 for an enclosed and gasketed roadway luminaire installed in an environment with less than 150 $\mu\text{g}/\text{m}^3$ airborne particulate matter and cleaned every four years.
 - c. Luminaire Ambient Temperature Factor (LATF) = 1.00
 - 2. Calculation/measurement points shall be per IES RP-8.
- E. Summary of reliability testing performed for LED driver(s)
- F. Written product warranty as per section 1.7 below
- G. Safety certification and file number
 - 1. Applicable testing bodies are determined by the US Occupational Safety Health Administration (OSHA) as Nationally Recognized Testing Laboratories (NRTL) and include: CSA (Canadian Standards Association), ETL (Edison Testing Laboratory), and UL (Underwriters Laboratory).
- H. Buy American documentation
 - 1. Manufacturers listed on the current NEMA Listing of Companies Offering Outdoor Luminaires Manufactured in U.S.A. for Recovery Act Projects need only provide a copy of the document.
 - 2. Other manufacturers shall submit documentation as per the DOE Guidance on Documenting Compliance with the Recovery Act Buy American Provisions (http://www1.eere.energy.gov/recovery/buy_american_provision.html).

1.7. WARRANTY

- A. Provide a minimum ten-year warranty covering maintained integrity and functionality of
 - 1. Luminaire housing, wiring, and connections
 - 2. LED light source(s)
 - a. Negligible light output from more than 10 percent of the LED packages constitutes luminaire failure.
 - 3. LED driver(s)
- B. Warranty period shall begin 90 days after date of invoice, or as negotiated by owner such as in the case of an auditable asset management system.

PART 2 – PRODUCTS

2.1. LUMINAIRE REQUIREMENTS

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A. General Requirements

1. Luminaires shall be as specified for each type in Appendix A.
2. Luminaire shall have an external label per ANSI C136.15
3. Luminaire shall have an internal label per ANSI C136.22.
4. Luminaire to have internal label of manufactured date visible when drive compartment opened.
5. Nominal luminaire input wattage shall account for nominal applied voltage and any reduction in driver efficiency due to sub-optimal driver loading.
6. Luminaires shall start and operate in -20°C to +40°C ambient.
7. Electrically test fully assembled luminaires before shipment from factory.
8. Effective Projected Area (EPA) and weight of the luminaire shall not exceed the values indicated in Appendix A.
9. Luminaires shall be designed for ease of component replacement and end-of-life disassembly.
10. Luminaires shall have tool-less entry for access to driver compartment
11. Luminaires shall be a minimum of IP65 rated
12. Luminaires must be available in 4000 K and 3000 K options
13. Luminaires shall be rated for the ANSI C136.31 Vibration Level indicated in Appendix A.
14. LED light source(s) and driver(s) shall be RoHS compliant.
15. Transmissive optical components shall be applied in accordance with OEM design guidelines to ensure suitability for the thermal/mechanical/chemical environment.

B. Driver

1. Rated case temperature shall be suitable for operation in the luminaire operating in the ambient temperatures indicated in section 2.1-A above.
2. Shall have a drive current no higher than 700mA
3. Shall accept the voltage or voltage range indicated in Appendix A at 50/60 Hz, and shall operate normally for input voltage fluctuations of plus or minus 10 percent.
4. Shall have a minimum Power Factor (PF) of 0.90 at full input power and across specified voltage range.
5. Control signal interface
 - a. Luminaire types indicated "Required" in Appendix A shall accept a control signal as specified via separate controls specification referenced in section 1.2 above, e.g., for dimming.
 - b. Luminaire types indicated "Not Required" in Appendix A need not accept a control signal.

C. Electrical immunity

1. Luminaire shall meet the "Basic" requirements in Appendix D. Manufacturer shall indicate on submittal form (Appendix E) whether failure of the electrical immunity system can possibly result in disconnect of power to luminaire.
2. Luminaire shall meet the "Elevated" requirements in Appendix D. Manufacturer shall indicate on submittal form (Appendix E) whether failure of the electrical immunity system can possibly result in disconnect of power to luminaire.

D. Electromagnetic interference

1. Shall have a maximum Total Harmonic Distortion (THD) of 20% at full input power and across specified voltage range.
2. Shall comply with FCC 47 CFR part 15 non-consumer RFI/EMI standards.

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- E. Electrical safety testing
 - 1. Luminaire shall be listed for wet locations by an OSHA NRTL.
 - 2. Luminaires shall have locality-appropriate governing mark and certification.
- F. Painted or finished luminaire components exposed to the environment
 - 1. Shall exceed a rating of six per ASTM D1654 after 1000hrs of testing per ASTM B117.
 - 2. The coating shall exhibit no greater than 30% reduction of gloss per ASTM D523, after 500 hours of QUV testing at ASTM G154 Cycle 6.
- G. Thermal management
 - 1. Mechanical design of protruding external surfaces (heat sink fins) for shall facilitate hose-down cleaning and discourage debris accumulation.
 - 2. Liquids or other moving parts shall be clearly indicated in submittals, shall be consistent with product testing, and shall be subject to review by Owner.
- H. IES TM-15 limits for Backlight, Uplight, and Glare (BUG Ratings) shall be as specified for each luminaire type in Appendix A.
 - 1. Calculation of BUG Ratings shall be for initial (worst-case) values, i.e., Light Loss Factor (LLF) = 1.0.
 - 2. If luminaires are tilted upward for calculations in section 1.6-D, BUG Ratings shall be calculated for the same angle(s) of tilt.
- I. Minimum Color Rendering Index (CRI): 70.
- J. Correlated Color Temperature (CCT)
 - 1. If nominal CCT specified in Appendix A is listed in Table 1 below, measured CCT and Duv shall be as listed in Table 1.

Table 1. Allowable CCT and Duv (adapted from NEMA C78.377)

| Manufacturer-Rated Nominal CCT (K) | Allowable LM-79 Chromaticity Values | |
|---------------------------------------|-------------------------------------|-----------------|
| | Measured CCT (K) | Measured Duv |
| 2700 | 2580 to 2870 | -0.006 to 0.006 |
| 3000 | 2870 to 3220 | -0.006 to 0.006 |
| 3500 | 3220 to 3710 | -0.006 to 0.006 |
| 4000 | 3710 to 4260 | -0.005 to 0.007 |
| 4500 | 4260 to 4746 | -0.005 to 0.007 |
| 5000 | 4745 to 5311 | -0.004 to 0.008 |
| 5700 | 5310 to 6020 | -0.004 to 0.008 |
| 6500 | 6020 to 7040 | -0.003 to 0.009 |

- 2. If nominal CCT specified in Appendix A is not listed in Table 1, measured CCT and Duv shall be as per the criteria for Flexible CCT defined in NEMA C78.377.
- K. The following shall be in accordance with corresponding sections of ANSI C136.37
 - 1. Wiring and grounding
 - a. All internal components shall be assembled and pre-wired using modular electrical connections.
 - 2. Mounting provisions
 - a. Specific configurations are indicated in Appendix A
 - 3. Terminal blocks for incoming AC lines
 - 4. Photocontrol receptacle
 - 5. Latching and hinging
 - 6. Ingress protection

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2.2. PRODUCT MANUFACTURERS

- A. Any manufacturer offering products that comply with the required product performance and operation criteria may be considered.

2.3. MANUFACTURER SERVICES

- A. Manufacturer or local sales representative shall provide installation and troubleshooting support via telephone and/or email.

END OF SECTION

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**APPENDIX A
MATERIAL SPECIFICATION
LUMINAIRE TYPE “A”**

| EXISTING LUMINAIRE TO BE REPLACED (FOR REFERENCE ONLY) | | |
|---|---|---|
| BENCHMARK LUMINAIRE: | Lamp wattage and type | 100 W HPS/ 150W MH |
| | Initial downward luminaire output (lumens below horizontal) | -- |
| | Light loss factor | 0.80 |
| LENS: | <input type="checkbox"/> Flat (“cutoff” style) <input checked="" type="checkbox"/> Sag/drop | |
| IES¹ FORWARD TYPE: | <input type="checkbox"/> I <input type="checkbox"/> II <input checked="" type="checkbox"/> III <input type="checkbox"/> IV <input type="checkbox"/> V <input type="checkbox"/> VS | |
| IES¹ LATERAL TYPE: | <input type="checkbox"/> Very short <input type="checkbox"/> Short <input checked="" type="checkbox"/> Medium <input type="checkbox"/> Long <input type="checkbox"/> Very long | |
| PERFORMANCE CRITERIA: LED LUMINAIRE | | |
| INPUT POWER: | Max. nominal luminaire input power | 105 W |
| NOMINAL CCT: | Rated correlated color temperature | 3000 K |
| PHOTOPIC² DOWNWARD LUMINAIRE OUTPUT: | Minimum <i>maintained</i> luminaire output below horizontal | |
| CUTOFF CLASSIFICATION | Full Cutoff Only | |
| VOLTAGE: | Nominal luminaire input voltage | 120/208/240 V |
| FINISH: | Luminaire housing finish color | Gray |
| WEIGHT: | Maximum luminaire weight | 30 lb |
| EPA: | Maximum effective projected area | 0.7 ft ² |
| MOUNTING: | Mtg. method | <input type="checkbox"/> Post-top <input checked="" type="checkbox"/> Side-arm <input type="checkbox"/> Trunnion/yoke <input type="checkbox"/> Swivel-tenon |
| | Tenon nominal pipe size (NPS) | |
| VIBRATION: | ANSI test level | <input checked="" type="checkbox"/> Level 1 (normal) <input type="checkbox"/> Level 2 (bridge/overpass) |
| DRIVER: | Control signal interface | <input checked="" type="checkbox"/> Not required <input type="checkbox"/> Required |

Appendix B

Estimating LED Lumen Maintenance

IES TM-21 allows for extrapolation of expected lumen maintenance from available test data. The extent of such extrapolation is limited by the duration of testing completed and the number of samples used in the testing. The TM-21 methodology shall be used by the manufacturer to determine lamp lumen depreciation (LLD) at end of lumen maintenance life per section 1.6-C.

The applicant may estimate lumen maintenance in one of two ways:

Option 1: Component Performance

Under this compliance path, the applicant must submit calculations per TM-21 predicting lumen maintenance at the luminaire level using In Situ Temperature Measurement Testing (ISTMT) and LM-80 data. To be eligible for the Component Performance option, ALL of the conditions below must be met. If ANY of the conditions is not met, the component performance option may not be used and the applicant must use Option 2 for compliance.

1. The LED light source(s) have been tested according to LM-80.
2. The LED drive current specified by the luminaire manufacturer is less than or equal to the drive current specified in the LM-80 test report.
3. The LED light source(s) manufacturer prescribes/indicates a temperature measurement point (T_s) on the light source(s).
4. The T_s is accessible to allow temporary attachment of a thermocouple for measurement of in situ temperature. Access via a temporary hole in the housing, tightly resealed during testing with putty or other flexible sealant is allowable.
5. For the hottest LED light source in the luminaire, the temperature measured at the T_s during ISTMT is less than or equal to the temperature specified in the LM-80 test report for the corresponding drive current or higher, within the manufacturer's specified operating current range.
 - a. The ISTMT laboratory must be approved by OSHA as a Nationally Recognized Testing Lab (NRTL), must be qualified, verified, and recognized through DOE's CALiPER program, or must be recognized through UL's Data Acceptance Program.
 - b. The ISTMT must be conducted with the luminaire installed in the appropriate application as defined by ANSI/UL 1598 (hardwired luminaires), with bird-fouling appropriately simulated (and documented by photograph) as determined by the manufacturer.

Option 2: Luminaire Performance

Under this compliance path, the applicant must submit TM-21 calculations based on LM-79 photometric test data for no less than three samples of the entire luminaire. Duration of operation and interval between photometric tests shall conform to the TM-21 criteria for LED light sources. For example, testing solely at 0 and 6000 hours of operation would not be adequate for the purposes of extrapolation.

Between LM-79 tests, the luminaire test samples must be operated long-term in the appropriate application as defined by ANSI/UL 1598 (hardwired luminaires). The test laboratory must hold

NVLAP accreditation for the LM-79 test procedure or must be qualified, verified, and recognized through the U.S. Department of Energy (DOE)'s CALiPER program. The extent of allowable extrapolation (either 5.5 or 6 times the test duration) depends on the total number of LED light sources (no less than 10 and preferably more than 19) installed in the luminaire samples, as per TM-21.

This compliance path poses a greater testing burden to luminaire manufacturers but incorporates long-term testing of other components in the system, such as drivers.

Under either compliance path, values used for extrapolation shall be summarized per TM-21 Tables 1 and 2. Submitted values for lumen maintenance lifetime and the associated percentage lumen maintenance shall be "reported" rather than "projected" as defined by TM-21. Supporting diagrams are requested to facilitate interpretation by Owner.

APPENDIX C PRODUCT FAMILY TESTING LM-79 AND ISTMT

It is recognized that due to the time and cost required for product testing, it would not be realistic to expect manufacturers offering a multitude of unique luminaire configurations to test every possible configuration. Therefore, the “product families” method may be utilized for LM-79 and ISTMT, whereby manufacturers identify a set of representative products for which test data can be used to demonstrate the accuracy of interpolated or extrapolated performance of product configurations lacking test data. Precedent for this approach can be found in LM-80.

If the particular luminaire configuration submitted has not been tested, the performance may be conservatively represented by test data for another luminaire configuration having:

- The same intensity distribution (typically only applies to LM-79)
- The same or lower nominal CCT
- The same or higher nominal drive current
- The same or greater number of LED light source(s)
- The same or lower percentage driver loading and efficiency
- The same or smaller size luminaire housing.

A more accurate estimate of performance can be obtained by linear interpolation between two or more tests differing in terms of the six parameters listed above. For example, consider a hypothetical luminaire offered in a single size housing, and having the following parameters:

- Three intensity distributions: IES Type II, III, or IV
- Three CCTs: 4000, 5000, and 6000K
- Three drive currents: 350, 525, and 700 mA
- Four LED quantities: 20, 40, 60, or 80 LEDs.

Table C.1 illustrates a set of tests which could allow for accurate interpolation between tested configurations, given a single luminaire housing size and essentially constant driver efficiency; these 10 tests may provide representative data for the 108 possible product configurations. Note that normalized intensity distribution must not be affected by the other three parameters.

Table C.1. Representative testing of a single luminaire housing size

| Tests | Intensity distribution (IES Type) | CCT (K) | Drive current (mA) | # of LEDs |
|----------|--------------------------------------|------------|-----------------------|------------|
| 1, 2, 3 | II, III, IV | 4000 | 700 | 80 |
| 4, 5 | IV | 5000, 6000 | 700 | 80 |
| 6, 7 | IV | 4000 | 325, 525 | 80 |
| 8, 9, 10 | IV | 4000 | 700 | 20, 40, 60 |

For example, the manufacturer could detail interpolation as shown in Table C.2, applying the following multipliers to the base test #2 to model a configuration with Type III intensity distribution, 5000K CCT, 525 mA drive current, and 40 LEDs:

- Ratio of test #4 lumens to test #3 lumens
- Ratio of test #7 lumens to test #3 lumens
- Ratio of test #9 lumens to test #3 lumens.

Table C.2. Multipliers for Test #2 to yield: Type III , 5000K, 525mA, 40 LEDs

| Test # | Intensity distribution (IES Type) | CCT (K) | Drive current (mA) | # of LEDs | Multiplier (lumens ratio) |
|--------|--------------------------------------|------------|-----------------------|-----------|------------------------------|
| 2 | III | 4000 | 700 | 80 | n/a |
| 3 | IV | 4000 | 700 | 80 | n/a |
| 4 | IV | 5000 | 700 | 80 | #4 / #3 |
| 7 | IV | 4000 | 525 | 80 | #7 / #3 |
| 9 | IV | 4000 | 700 | 40 | #9 / #3 |

Interpolation between minimal LM-79 and ISTMT data is more difficult if housing size increases with increasing wattage; it may not be clear whether the lowest-wattage configuration would be expected to “run cooler” than the highest-wattage configuration. In these circumstances, the adequacy of submitted data is subject to Owner approval.

At this time, the “successor” method cannot be used; luminaires tested must utilize the LED light source(s) characterized by the submitted LM-80 report.

APPENDIX D

ELECTRICAL IMMUNITY

Test Procedure

- Electrical Immunity Tests 1, 2 and 3, as defined by their Test Specifications, shall be performed on an entire powered and connected luminaire, including any control modules housed within the luminaire, but excluding any control modules mounted externally, such as a NEMA socket connected photo-control. A shorting cap should be placed across any such exterior connector.
- The luminaire shall be connected to an AC power source with a configuration appropriate for nominal operation. The AC power source shall have a minimum available short-circuit current of 200A. The luminaire shall be tested at the nominal input voltage specified in Appendix A, or at the highest input voltage in the input voltage range specified in Appendix A.
- Electrical Immunity test waveforms shall be superimposed on the input AC power line at a point within 6 inches (15cm) of entry into the luminaire using appropriate high-voltage probes and a series coupler/decoupler network (CDN) appropriate for each coupling mode, as defined by ANSI/IEEE C62.45-2002. The test area for all tests shall be set up according to ANSI/IEEE C62.45-2002, as appropriate.
- Prior to electrical immunity testing a set of diagnostic measurements shall be performed, and the results recorded to note the pre-test function of the luminaire after it has reached thermal equilibrium. These measurements should include at a minimum:
 - a) For all luminaires, Real Power, Input RMS Current, Power Factor and THD at full power/light output
 - b) For luminaires specified as dimmable, Real Power, Input RMS Current, Power Factor and THD at a minimum of 4 additional dimmed levels, including the rated minimum dimmed level
- Tests shall be applied in sequential order (Test 1, followed by Test 2, followed by Test 3). If a failure occurs during Test 3, then Test 3 shall be re-applied to a secondary luminaire of identical construction.
- Following the completion of Tests 1, 2, and 3, the same set of diagnostic measurements performed pre-test should be repeated for all tested luminaires, and the results recorded to note the post-test function of the luminaire(s).
- A luminaire must function normally and show no evidence of failure following the completion of Test 1 + Test 2 + Test 3 (for a single tested luminaire), or the completion of Test 1 + Test 2 on a primary luminaire and Test 3 on a secondary luminaire. Abnormal behavior during testing is acceptable.
- A luminaire failure will be deemed to have occurred if any of the following conditions exists following the completion of testing:
 - a) A hard power reset is required to return to normal operation
 - b) A noticeable reduction in full light output (e.g. one or more LEDs fail to produce light, or become unstable) is observed
 - c) Any of the post-test diagnostic measurements exceeds by $\pm 5\%$ the corresponding pre-test diagnostic measurement.
 - d) The luminaire, or any component in the luminaire (including but not limited to an electrical connector, a driver, a protection component or module) has ignited or shows evidence of

melting or other heat-induced damage. Evidence of cracking, splitting, rupturing, or smoke damage on any component is acceptable.

Test Specifications

NOTE: L1 is typically “HOT”, L2 is typically “NEUTRAL” and PE = Protective Earth.

Test 1) Ring Wave: The luminaire shall be subjected to repetitive strikes of a “C Low Ring Wave” as defined in IEEE C62.41.2-2002, Scenario 1, Location Category C. The test strikes shall be applied as specified by Table D.1. Prior to testing, the ring wave generator shall be calibrated to simultaneously meet BOTH the specified short circuit current peak and open circuit voltage peak MINIMUM requirements. Note that this may require that the generator charging voltage be raised above the specified level to obtain the specified current peak. Calibrated current probes/transformers designed for measuring high-frequency currents shall be used to measure test waveform currents.

Test waveform current shapes and peaks for all strikes shall be compared to ensure uniformity throughout each set (coupling mode + polarity/phase angle) of test strikes, and the average peak current shall be calculated and recorded. If any individual peak current in a set exceeds by $\pm 10\%$ the average, the test setup shall be checked, and the test strikes repeated.

Table D.1: 0.5 μ S – 100Hz Ring Wave Specification

| Parameter | Test Level/Configuration |
|----------------------------|--|
| Short Circuit Current Peak | 0.5 kA |
| Open Circuit Voltage Peak | 6 kV |
| Source Impedance | 12 Ω |
| Coupling Modes | L1 to PE, L2 to PE, L1 to L2 |
| Polarity and Phase Angle | Positive at 90° and Negative at 270° |
| Test Strikes | 5 for each Coupling Mode and Polarity/Phase Angle combination |
| Time between Strikes | 1 minute |
| Total Number of Strikes | = 5 strikes x 4 coupling modes x 2 polarity/phase angles = 40 total strikes |

Test 2) Combination Wave: The luminaire shall be subjected to repetitive strikes of a “C High Combination Wave” or “C Low Combination Wave”, as defined in IEEE C62.41.2-2002, Scenario 1, Location Category C. The test strikes shall be applied as specified by Table D.2. The “Low” test level shall be used for luminaires with **Basic** Electrical Immunity requirements, while the “High” test level shall be used for luminaires with **Elevated** Electrical Immunity requirements. Prior to testing, the combination wave generator shall be calibrated to simultaneously meet BOTH the specified short circuit current peak and open circuit voltage peak MINIMUM requirements. Note that this may require that the generator charging voltage be raised above the specified level to obtain the specified current peak. Calibrated current probes/transformers designed for measuring high-frequency currents shall be used to measure test waveform currents.

Test waveform current shapes and peaks for all strikes shall be compared to ensure uniformity throughout each set (coupling mode + polarity/phase angle) of test strikes, and the average peak current shall be calculated and recorded. If any individual peak current in a set exceeds by $\pm 10\%$ the average, the test setup shall be checked, and the test strikes repeated.

Table D.2: 1.2/50 μ S – 8/20 μ S Combination Wave Specification

| Parameter | Test Level/ Configuration | |
|--|--|------------|
| 1.2/50 μ S Open Circuit Voltage Peak | Low: 6 kV | High: 10kV |
| 8/20 μ S Short Circuit Current Peak | Low: 3 kA | High: 10kA |
| Source Impedance | 2 Ω | |
| Coupling Modes | L1 to PE, L2 to PE, L1 to L2 | |
| Polarity and Phase Angle | Positive at 90° and Negative at 270° | |
| Test Strikes | 5 for each Coupling Mode and Polarity/Phase Angle combination | |
| Time Between Strikes | 1 minute | |
| Total Number of Strikes | = 5 strikes x 4 coupling modes x 2 polarity/phase angles = 40 total strikes | |

Test 3) Electrical Fast Transient (EFT): The luminaire shall be subjected to “Electrical Fast Transient Bursts”, as defined in IEEE C62.41.2 -2002. The test area shall be set up according to IEEE C62.45-2002. The bursts shall be applied as specified by Table D.3. Direct coupling is required; the use of a coupling clamp is not allowed.

Table D.3: Electrical Fast Transient (EFT) Specification

| Parameter | Test Level/ Configuration |
|---------------------------|--|
| Open Circuit Voltage Peak | 3 kV |
| Burst Repetition Rate | 2.5 kHz |
| Burst Duration | 15 mS |
| Burst Period | 300 mS |
| Coupling Modes | L1 to PE, L2 to PE, L1 to L2 |
| Polarity | Positive and Negative |
| Test Duration | 1 minute for each Coupling Mode and Polarity combination |
| Total Test Duration | = 1 minute x 7 coupling modes x 2 polarities = 14 minutes |

APPENDIX E
PRODUCT SUBMITTAL FORM

| | | |
|---|--|---|
| Luminaire Type ¹ | | |
| Manufacturer | | |
| Model number | | |
| Housing finish color | | |
| Tenon nominal pipe size (inches) | | |
| Nominal luminaire weight (lb) | | |
| Nominal luminaire EPA (ft ²) | | |
| Nominal input voltage (V) | | |
| ANSI vibration test level | <input checked="" type="checkbox"/> Level 1 (Normal) | <input type="checkbox"/> Level 2 (bridge/overpass) |
| Nominal BUG Ratings | | |
| Make/model of LED light source(s) | | |
| Make/model of LED driver(s) | | |
| Dimmability | <input type="checkbox"/> Dimmable | <input checked="" type="checkbox"/> Not dimmable |
| Control signal interface | | |
| Upon electrical immunity system failure | <input type="checkbox"/> Possible disconnect | <input type="checkbox"/> No possible disconnect |
| Thermal management | <input type="checkbox"/> Moving parts | <input checked="" type="checkbox"/> No moving parts |
| Lumen maintenance testing duration (hr) | | |
| Reported lumen maintenance life (hr) ² | | |
| Warranty period (yr) | | |
| Parameter | Nominal value | Tolerance (%) |
| Initial photopic output (lm) | | |
| Maintained photopic output (lm) | | |
| Lamp lumen depreciation | | |
| Initial input power (W) | | |
| Maintained input power (W) | | |
| Initial LED drive current (mA) | | |
| Maintained LED drive current (mA) | | |
| Drive current used | | |
| In-situ LED T _c (°C) | | |
| CCT (K) | | |
| Additional product description | | |

¹ See Appendix A, and attach supporting documentation as required.

² Value shall be no less than as specified in section 1.6-C, and shall not exceed six times the testing duration indicated in the row above. Value shall be consistent with values submitted in the rows below for maintained light output, maintained input power, and maintained drive current.